Imaging Surveys at the VLT Survey Telescope

Abstract

The VLT Survey Telescope (VST) is a 2.6-m optical wide-field telescope installed at the ESO observatory of Cerro Paranal (Chile). The only instrument at the VST is OmegaCAM, which is a wide-field camera, covering 1 square degree in the sky, with 0.21 arcsec per pixel. On 1st October 2022, after more than 10 years of activity, the INAF-ESO contract expired and the VST became a hosted telescope at ESO. VST is currently owned and managed by INAF, and a new 5-year, 2022-2027 (renewable) INAF-ESO agreement was signed to define rules and roles.

Since then, the INAF-Coordination Centre for the VST is in charge of managing the operations at the VST.

The VLT Survey Telescope (VST) has been one of the most efficient wide-field imagers in the optical bands since the start of operations in 2011.

The VST has played a pivotal role in expanding our understanding of the universe. By surveying the night sky with unparalleled precision, this telescope has provided astronomers with a wealth of data on a diverse range of astronomical phenomena, from distant galaxies and clusters to galactic objects.

In the following sections we describe a collection of imaging data obtained using VST, detailing the use of different specific filters to enhance observational capabilities.

The dataset, gathered using high-resolution imaging techniques, spans a wide range of celestial objects, from distant galaxies' clusters to nearby galaxies and star clusters. The observations have been conducted by using almost all the VST filters, e.g. u,g,r,i,z,H_α, allowing for precise photometric measurements and detailed color analyses of the captured objects, enhancing the dataset's utility for researchers exploring various astrophysical phenomena. This release also includes some data taken before the new INAF-ESO agreement.

This VST imaging data collection, with its extensive filter coverage, stands as a valuable asset for observational astronomers, enabling in-depth studies of the universe's structures and characteristics.

We plan to release new reduced data twice a year. New survey projects will be added, along with additional data to the already released ones.

Overview of Observations

The data released belong to the survey projects explained in details below. Targets, covered area, filters and total exposure times of the data in this collection are listed in Table 1.

1) The "VST Early-type Galaxy Survey (VEGAS, P.I. E. Iodice)" provides deep multi-band (u,g,r,i) images of early-type galaxies (ETGs) in different environments. Taking advantage of the wide (1 square degree) field-of-view of OmegaCAM@VST, the long integration time, and the wide variety of targets, VEGAS turned out to be a gold mine to explore the structure of galaxies down to the faintest surface brightness levels of $\mu g \sim 27-30$ mag/arcsec^{2}, in dense clusters of galaxies as well as in the unexplored poor groups of galaxies and to provide the set of observables that can be directly compared with the theoretical predictions.

For fields containing bright and extended galaxies (with mB $\leq$ 10 mag and a major axis diameter $\geq$ 3 arcmin), the best background estimate is achieved by adopting the step-dither observing strategy. This mimics the ON-OFF procedure devised in infrared astronomy where the background is estimated from exposures taken as close as possible, in space and time, to the scientific ones.

Therefore, the step-dither strategy used for the VEGAS images consists of a cycle of short exposures (150 sec) on the science target and on an adjacent field (close in space and time) to the science frame.

The adopted offset in the observing sequence is ≤ 0.3 deg and the directions of these small offsets were randomly chosen around the center of each field. An average sky image, for each night, is derived from the sky frames, which is then scaled and subtracted from the science frames.
For less extended objects (with a major axis diameter D ≤ 3 arcmin), the standard diagonal observing strategy has been adopted, since the sky background can be estimated on the science frame, by using a polynomial surface fit over the entire frame (see Capaccioli et al. 2015).

Some of the targets of the VEGAS project were released under the Phase3 collection 'VEGAS'.
Most of the data have been processed using the Astro-WISE data-reduction pipeline, while 3% of the dataset has been reduced using the VST-Tube data-reduction pipeline. Data from this survey can be selected via the header keyword "SUR_REG = 'VEGAS'" and/or via "PROG_ID" header keywords, where the PROG_IDs are the following: 096.B-0582(B), 097.B-0806(A), 098.B-0208(A), 099.B-0560(A), 0100.B-0168(A), 0101.A-0166(A), 0102.A-0669(A), 0103.A-0181(B), 0104.A-0072(A).

2) The project "VST Optical Data to Advance SKA Precursors Science (VST_SKA, P.I. N. Napolitano)" aims to leverage the imaging capabilities of the VLT Survey Telescope (VST) to provide crucial optical data that complements and enhances the scientific goals of precursor projects to the Square Kilometre Array (SKA) radio telescope. By using the VST's high-resolution imaging and extensive field coverage, the project seeks to contribute valuable insights into various astrophysical phenomena that are of interest to the SKA precursor initiatives.
The survey has been conducted on ELAIS-S1 (ES1) fields. These areas are of paramount interest to the community as they have been surveyed by Spitzer (SWIRE) and are also the target of deep NIR (VISTA-VIDEO), MIR (Spitzer-SERVS) and FIR (Herschel- HerMES) observations, as well as GALEX (UV) and ATLAS (radio) (see e.g. Figure 1) but were missing high-quality optical imaging. The observing strategy implemented includes time series in g and i–band to additionally perform AGN variability.
The data have been processed with Astro-WISE. Data from this survey can be selected via the header keyword "SUR_REG = VST_SKA" and/or via "PROG_ID" header keywords, where the PROG_IDs are the following: 105.20R5.002, 108.227E.002, 110.256G.002.

3) The "Pre-supernova outbursts in Galactic Red Supergiants: predicting the next Galactic SN event (GALRSG, P.I. F. Bocchino)" is a monitoring program aimed to characterize the multi-color light curves of a coeval and co-distant sample of RSGs in the Scutum-Crux region (see Figure 2), to detect late-stage outbursts and to compare them with the very recent models of the final phases of low-mass RSGs before SN explosion, thus possibly predicting core collapse before it occurs. This program carries out dedicated monitoring of the RSG catalog in the i and z bands of a large highly absorbed area of the galactic plane with a cadence of a few days, and it will likely remain a very good choice also in the LSST era.
The data have been processed with Astro-WISE data reduction pipeline. Data from this survey can be selected via the header keyword "SUR_REG = GALRSG" and/or via "PROG_ID" header keywords, where the PROG_ID is the following: 110.25AN.001.

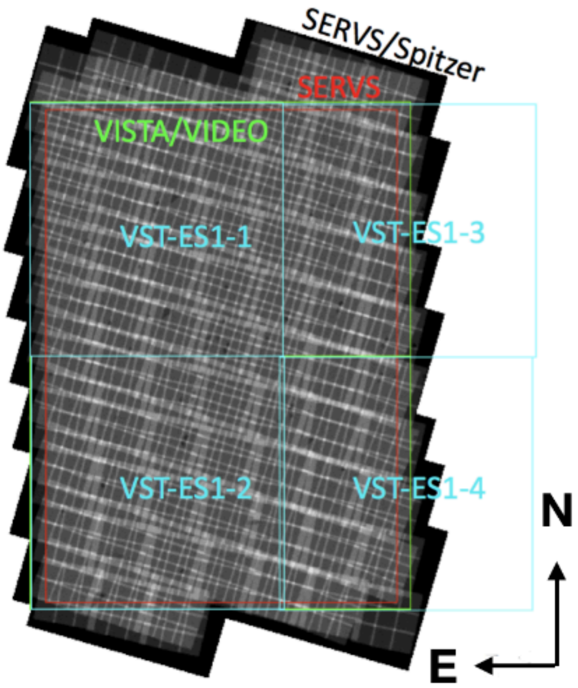

Figure 1: Field distribution of VST deep observations from the VST_SKA project, and existing MIR and NIR observations.

4) The "Stellar Explosions and their Evolution In Nearby Galaxies (SEEING, P.I. L. Izzo) with the VST" aims at detecting classical novae in nearby galaxies with the goal to determine their explosion rate, a fundamental ingredient for the role of novae in chemical evolution studies, and as a proxy for their progenitors' stellar populations. Moreover, the cadence used will also allow us to discover and follow up intermediate-luminosity transients such as luminous blue variables and red novae, in addition to hunting for progenitor stars of direct collapse black holes. The final multi-filter stacked mosaics, obtained from the entire set of images of every single galaxy, will be useful
as an atlas for detailed stellar population studies, to search for low-surface brightness satellites and as a template for higher redshift transients, exploding in the background galaxies. The methodology developed in this two-year program is already serving as a training preparatory work for future studies available with the incoming Vera Rubin telescope.
The goal of the project consists in measuring the properties of classical novae (CNe) in very nearby galaxies (e.g. d < 7 Mpc) using VST detections and follow-up of newly discovered events. The galaxy sample has been selected in order to maximize its coverage in both g and r bands.
The data have been processed with the VST pipeline. Data from this survey can be selected via the header keyword "SUR_REG = SEEING" and/or via "PROG_ID" header keywords, where the PROG_ID is the following: 110.25A9.001

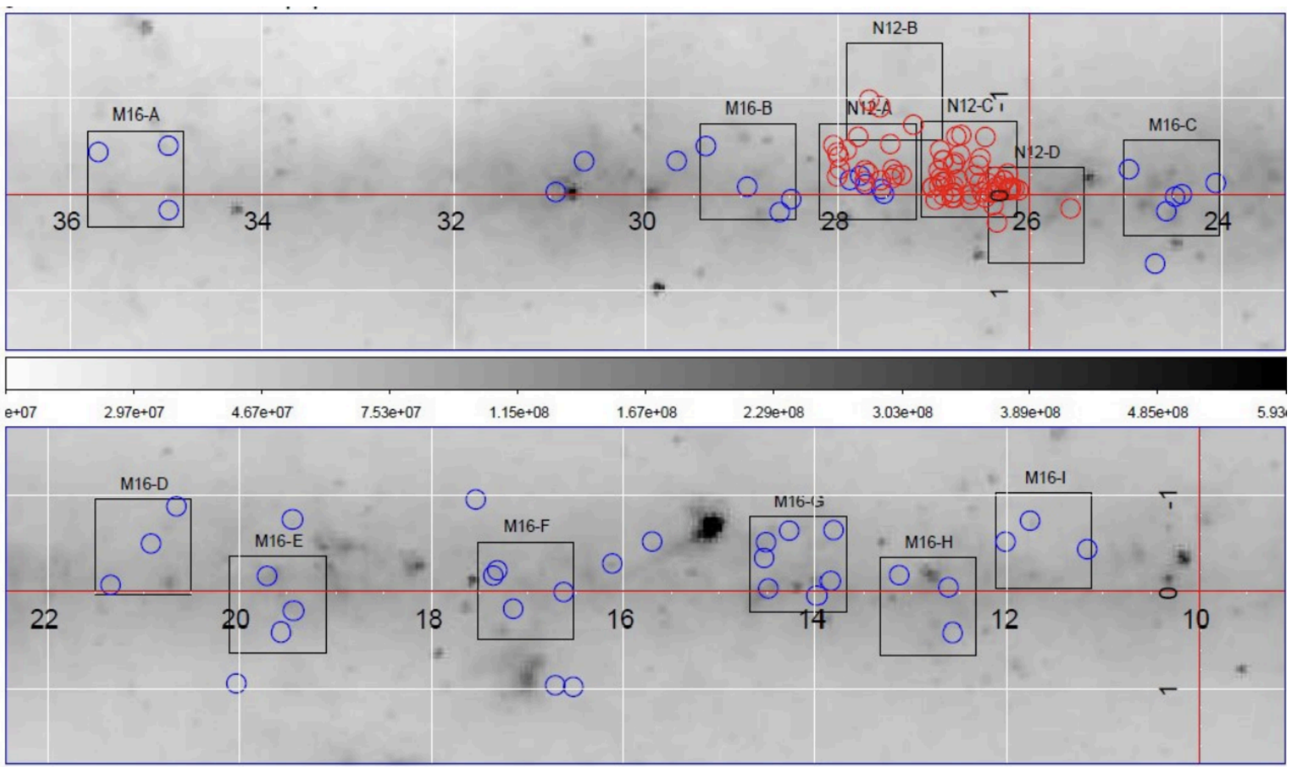

Figure 2: Top panel: A grey-scale image of the 12 μm band emission of the Galactic plane in the range 23° < l < 37° and -1.5° <b < 1.5° as observed by IRAS, on which have been overimposed the sources of Neguerela+ (2012, N12, red circles) and of Messineo+ (2016, M16, blue circles) selected for this monitoring campaign. Black boxes are 1° × 1° VST OmegaCAM pointings of the campaign. The location of the pointings have been chosen to have at least 3 sources from the proposed list in the OmegaCAM FOV and to maximize the coverage of the set. Bottom panel: Same as the top panel but for 10° < l < 22 °

5) The project “Search for SN explosions from Pop III ”analogs” in the Local Universe (SN, P.I. M. Della Valle)” aims to use VST to search for “Pop III SN-like” events in the relatively nearby Universe (z < 1). These objects should be detected as super luminous supernovae, characterized by long-lasting maxima, produced
in the explosions of pair instability supernovae occurring in progenitor stars with masses > 100 Msun. This program carried out in the nearby universe is designed to prepare future research/observations of “genuine” Pop III supernovae which will be carried on with LSST and JWST. Targets have been selected considering several constraints, such as the extragalactic field, including also cluster lenses (which would allow us to search also for high-redshift lensed supernovae) and deep fields such as the COSMOS and the HDF South, and observed in g and r bands.
The data have been processed with the VST pipeline. Data from this survey can be selected via the header keyword “SUR_REG = SN” and/or via “PROG_ID” header keywords, where the PROG_ID is the following: 110.25AB.001.

6) The “Galaxy Assembly as a function of Mass and Environment with VST” survey (VST-GAME, P.I. A. Mercurio) is aimed at gathering deep (r < 24.4) and wide (approx. 20x20 Mpc^2) observations at optical (u, g, r, i) wavelengths for six massive galaxy clusters at 0.2 < z < 0.6. In this collection are released the r and i band images of the RXJ2248 cluster (also known as AS1063), which are 20 OBs in the r band (20 hours of exposure time), and 8 OBs in the i band (approximately 8 hours of exposure time).
Each OB consists of 5 dither exposures of 608 seconds each in the r band, and 5 dither exposures of 590 seconds each in the i band, centered on the cluster's coordinates 22:48:44.0; -44:31:51.0, with a small shift between each exposure to cover the gaps.
The overall objective of these observations is to study the evolution of galaxies in the outskirts of the RXJ2248 cluster. These data are part of a multi-band survey that includes complementary data from other instruments, among which the most relevant for studying the properties of galaxies are those from NIRCAM@VISTA in the J, Y, and Ks bands.

The data have been processed with VST-Tube data-reduction pipeline.Data from this survey can be selected via the header keyword "SUR_REG = VST-GAME" and/or via "PROG_ID" header keywords, where the PROG_ID is the following: 110.256F.003.

Targets, covered area, filters and total exposure times of the data in this collection are listed in Table 1. In this table, the adopted observing strategy for each target is also included. The various data reduction pipelines utilized are described in the following sections.

Release Content

Target (1)	RA [h m s] (2)	Dec [d m s] (3)	u' [sec] (4)	g' [sec] (5)	r' [sec] (6)	i' [sec] (7)	z' [sec] (8)	Area [deg^2] (9)	Strategy (10)	Prog. (11)
HCG 86	19:51:59.00	-30:49:31.00	-	18000	12300	7200	-	1	Standard	VEGAS
NGC 3311	10:36:42.80	-27:31:41.23	-	20100	23250	-	-	5	Step-dither	VEGAS
NGC 3379	10:47:49.60	+12:34:53.76	14700	16800	17550	-	-	3,9	Step-dither	VEGAS
NGC 3640	11:21:06.84	+03:14:05.71	11250	8550	8250	8250	-	2	Step-dither	VEGAS
PGC 007748	02:02:17.28	-01:07:40.25	-	21600	7200	-	-	1	Standard	VEGAS
PGC 015524	04:33:37.83	-13:15:42.95	-	10440	9000	-	-	1	Standard	VEGAS
PGC 049940	14:01:41.84	-11:36:24.97	-	9000	9000	-	-	1	Standard	VEGAS
ES1-1	21:14:58.60	-34:31:26.25	-	28150	31030	34580	-	1	Standard	VST_SKA
ES1-2	21:14:30.11	-34:31:26.25	-	60050	32860	81420	-	1	Standard	VST_SKA
ES1-3	21:19:08.16	-35:34:59.59	-	23250	27100	44080	-	1	Standard	VST_SKA
ES1-4	21:19:30.67	-34:38:11.77	-	23560	52840	42560	-	1	Standard	VST_SKA
M16-A	18:56:23.1	+02:02:49	-	-	-	2700	2700	1	Standard	GALRSG
M16-B	18:44:58.0	-03:39:53	-	-	-	3450	3443	1	Standard	GALRSG
M16-C	18:36:14.4	-07:30:52	-	-	-	900	900	1	Standard	GALRSG
M16-D	18:31:06.4	-07:30:52	-	-	-	6301	6298	1	Standard	GALRSG
M16-E	18:26:17.2	-10:49:09	-	-	-	6417	6302	1	Standard	GALRSG
M16-F	18:21:52.1	-14:07:58	-	-	-	300	300	1	Standard	GALRSG
M16-G	18:17:17.6	-16:45:16	-	-	-	1350	1350	1	Standard	GALRSG
M16-H	18:13:00.2	-17:43:59	-	-	-	900	900	1	Standard	GALRSG
M16-I	18:13:04.6	-19:07:37	-	-	-	600	600	1	Standard	GALRSG
N12-A	18:42:40.6	-04:46:36	-	-	-	750	750	1	Standard	GALRSG
N12-B	18:45:09.8	-05:23:40	-	-	-	300	300	1	Standard	GALRSG
N12-C	18:40:51.9	-05:43:31	-	-	-	300	300	1	Standard	GALRSG
N12-D	18:37:50.9	-06:07:34	-	-	-	300	300	1	Standard	GALRSG
S-M16-J	09:04:11.89	-60:45:55.26	-	-	-	900	900	1	Standard	GALRSG
S-M16-K	07:43:26.48	-61:44:50.50	-	-	-	150	150	1	Standard	GALRSG

S-M16-L	09:23:29.20	-59:56:01.44	-	-	-	750	750	1	Standard	GALRSG
S-M16-M	07:24:00.53	-61:00:44.61	-	-	-	450	450	1	Standard	GALRSG
S-M16-N	07:24:00.31	-61:00:44.84	-	-	-	450	450	1	Standard	GALRSG
Carina	22:42:47.3	-64:28:09	-	2700	7200	-	-	1	Standard	SEEING
ESO 270-017	13:34:47.3	-45:32:51	-	8100	18180	-	-	1	Standard	SEEING
ESO 274-001	15:14:13.5	-46:48:45	-	9900	18180	-	-	1	Standard	SEEING
NGC 3109	10:03:09.7	-26:22:18	-	3600	11340	-	-	1	Standard	SEEING
NGC 3521	11:05:48.58	-00:02:09.11	-	6300	11880	-	-	1	Standard	SEEING
NGC 4945	13:05:26.1	-49:28:16	-	9000	19800	-	-	1	Standard	SEEING
NGC 5068	13:18:55.3	-21:02:21	-	3600	6300	-	-	1	Standard	SEEING
NGC 5128	13:25:28.9	-43:01:00	-	9000	19800	-	-	1	Standard	SEEING
NGC 5236	13:37:00.1	-29:52:04	-	7200	9900	-	-	1	Standard	SEEING
NGC 6744	19:09:46.18	-63:51:26.99	-	8100	17280	-	-	1	Standard	SEEING
NGC 7090	21:36:28.81	-54:33:25.30	-	7200	17100	-	-	1	Standard	SEEING
Sextans B	10:00:36.4	05:08:45	-	4500	11700	-	-	1	Standard	SEEING
WLM	00:01:58.1	-15:27:40	-	3600	7740	-	-	1	Standard	SEEING
MACS J1115	11:15:52	+01:29:57	-	6000	6000	-	-	1	Standard	SN
MACS J1206	12:06:12	-08:48:02	-	7500	7500	-	-	1	Standard	SN
MACS J1311	13:11:01	-03:10:39	-	9000	9000	-	-	1	Standard	SN
MACS J1931	19:31:50	+01:29:57	-	9000	9000	-	-	1	Standard	SN
MS 2137	21:40:15	-23:39:41	-	7500	7500	-	-	1	Standard	SN
RX J1347	13:48:31	-11:45:01	-	9000	9000	-	-	1	Standard	SN
RXJ2248	22:48:44.0;	-44:31:51.0	-	-	3040	2950	-	1	Standard	VST-GAME

Table 1. Target list of this collection. In column 1 is given the target name. In columns 2 and 3 are listed the J2000 celestial coordinates. From columns 4 to 8 are reported the total integration time for each 1 square deg field, in the u', g', r', i', and z' bands respectively. In column 9 is indicated the total covered area of the mosaic. In columns 10 and 11 are indicated the adopted observing strategy and the project associated with the data.

Release Notes

Data Reduction and Calibration

Data belonging to this release have been reduced using different software, the information can be found in the file header under the keyword PROCSOFT. Below an overview of the different pipelines used.

Astro-WISE

Part of the data released in this collection has been reduced by using the Astronomical Wide-field Imaging System for Europe (Astro-WISE) pipeline (McFarland et al. 2013), also used for the KIDS survey. The instrumental corrections applied for each frame include overscan correction, removal of bias, flat-fielding, illumination correction, masking of the bad pixels, and subtraction of the background.

- **De-biasing and overscan correction**. The data is overscan corrected by subtracting from each pixel row the row-wise median values, read from the CCD overscan areas. The fine structure of the bias is then subtracted using a master bias frame stacked from ten overscan corrected bias frames.
- **Flat-fielding.** Flatfielding is done after bias correction using a master flat-field which is combined from twilight flatfields and dome flatfields. Before combining the different flat-fields, the high spatial frequencies are filtered out from the twilight flat-fields, and the low frequency spatial Fourier frequencies from the dome flat-fields.
- **Weight maps.** During the instrumental reduction, weight maps are also created for each individual frame. Weight maps carry information about the defects or contaminated pixels in the images and also the expected noise associated with each pixel. The hot and cold pixels are detected from the bias and flatfield images, respectively. These pixels are then set to zero in the weight maps. The flatfielded and debiased images are also searched for satellite tracks and cosmic rays, and the values of the pixels in the weight maps corresponding to the contaminated pixels in the science images, are then set to zero.
- **Illumination correction.** Systematic photometric residual patterns still remain after flat-fielding, which are corrected by applying an illumination correction to the data. The correction models are made by mapping the photometric residuals across the OmegaCAM's CCD array using a set of dithered observations of Landolt's Selected Area (SA) standard star fields (A.U. Landolt, 1992, AJ, 104, 340), and fitting a linear model to the residuals. The images were multiplied with this illumination correction. The illumination correction is applied after the background removal to avoid producing artificial patterns in the background of images.
- **De-fringing.** De-fringing is only needed for i-band. Analysis of nightly fringe frames showed that the pattern is constant in time. For each science exposure this fringe image is scaled (after background subtraction of the science exposure and fringe frame) and then subtracted to minimize residual fringes.
- **Astrometric calibration.** The first-order astrometric calibration was done by first matching the pixel coordinates to RA and Dec using the World Coordinate System (WCS) information from the fits header. Point source coordinates were then extracted using SExtractor and associated with the 2 Micron All Sky Survey Point Source Catalog (2MASS PSC, Skrutskie et al. 2006). The transformation was then extended by a second-order two-dimensional polynomial across the focal plane. SCAMP (Bertin 2006) was used for this purpose. The polynomial was fit iteratively five times, each time clipping the 2σ-outliers. The astrometric solution gives typically rms errors of 0.3 arcsec (compared to 2MASS PSC) for a single exposure, and 0.1 arcsec for the stacked final mosaic.
- **Photometric calibration.** The absolute photometric calibration was performed by observing standard star fields each night and comparing their OmegaCAM magnitudes with the Sloan Digital Sky Survey Data Release 11 (SDSS DR11, Alam et al. 2015) catalog values. The OmegaCAM point source magnitudes were first corrected for the atmospheric extinction by subtracting a term kX, where X is airmass and k is the atmospheric extinction coefficient with the values of 0.182, 0.102 and 0.046 for g′, r′ and i′, respectively. The zero-point for a given CCD is the difference between the object's corrected magnitude measured from a standard star field exposure and the catalog value. The zero-point for each CCD was kept constant for the whole night, only correcting for the varying airmass.
- **Background subtraction.** For images observed with the step-dither strategy, a background model is created first by scaling a set of 12 consecutive exposures of the targets, and then median averaging the stack. The scaling factors between images A and B is defined by measuring median values within small boxes in image A (mA), and in the same locations in image B (mB), and then taking the median of their ratios: s = median(mA/mB) For each image among those to be stacked, such a scaling factor is defined with respect to A, and the images are multiplied with these factors before stacking. If there is a large scatter between the ratios of s, the chip medians of the exposures are scaled with each other. The scaled images are then median stacked to the background model, and the model is subtracted from image A.
- **Regridding and coadding.** After the astrometric and photometric calibrations, the images were sampled to 0.20 arcsec pixel size and combined using the SWarp software (Bertin 2010). Before combining the images, cosmic rays and bad pixels were removed using the weight maps.

VST-Tube

Some of the data in this collection were processed with the VST-tube pipeline (Grado et al. 2012). A detailed description of all data-reduction steps is given by Capaccioli et al. (2015). In short, they include:
1. pre-reduction
2. astrometric and photometric calibration
3. mosaic production

In the pre-reduction process, science images are treated to remove the instrumental signatures, applying overscan, bias, and flat-field corrections, as well as gain harmonization of the 32 CCDs, illumination correction and, for the i'-band, defringing. The absolute photometric calibration is performed by comparing the OmegaCAM magnitudes of the standard star fields observed during each night with SDSS DR8 photometry. For each night and band, the zero point (ZP) and color term were obtained using the tool Photcal (Radovich et al. 2004). The extinction coefficient was derived from the extinction curve M.OMEGACAM.2011-12-01T16:15:04.474 provided by ESO. Relative photometric correction among the exposures was obtained by minimizing the quadratic sum of magnitude differences between overlapping detections, by using the SCAMP task (Bertin 2006). The final coadded images were then normalized to an exposure time of one second and a ZP = 30 mag. To obtain the absolute and relative astrometric calibrations we used the SCAMP task. For the absolute astrometric calibration, we refer to the 2MASS catalog. Finally, the image resampling, where the astrometric solution is applied, and the final image coaddition are made with SWARP (Bertin et al. 2002). As an additional task, the VST-tube pipeline can provide sky-subtracted mosaics. For images obtained with the standard observing technique (using diagonal dithers), the sky background is modelled fitting a surface, typically a 2D polynomial, to the pixel values of the mosaic, where all bright sources are masked. The mask is made by using the ExAM task (Huang et al. 2011), a program based on SExtractor (Bertin & Arnouts 1996), which was developed to accurately mask background and foreground sources, as well as reflection haloes and spikes from saturated stars. For the images acquired with the step-dither observing strategy, the background is estimated from exposures taken as sky frames. For each observing night, the pipeline produces an average sky frame which is scaled and subtracted to each science frame.

VST pipeline

The VST pipeline is a code entirely written in python (Izzo et al. in preparation). The pipeline utilizes several packages developed for astronomical image analysis, including *astropy* and *ccdproc*, and operates on each individual sensor of the 32 OmegaCam frames.
All calibration and science frames are treated as "objects" using the *CCDData* routine available within *ccdproc*. Bias subtraction and flat-field correction of science and standard frames are then applied after calculating the gain and read-out noise from individual bias and flat-field frames. Currently, the pipeline does not perform illumination correction, though this functionality will be implemented soon. Subsequently, all frames are registered to the same spatial grid and photometric scale using *astrometry.net*, which is run locally.

Following registration, single frames from each of the five dithered exposures per epoch are median-averaged and background-subtracted using the *swarp* software, resulting in a stacked image. To refine the plate-solving correction, *scamp* is run on each stacked image. The pipeline also generates a weighted pixel image, which tracks the number of dithered exposures contributing to the combined image, and a mask frame, which accounts for CCD gaps, bad pixels, and cosmic ray rejection, with both images provided as FITS files. Finally, the pipeline was employed to produce deep stacked images by combining all single stacked images for each epoch and in a given filter.

Data Quality

In Table 2 we report the limiting magnitudes and the average FWHM within the field, for each set of observations and in the different photometric bands. Same information is also reported in the image header. The limiting magnitude is the surface brightness of a point source corresponding at 5σ of the background noise in the image. The RMS error of the astrometric solution is ~0.3 arcsec.

Target	**FWHM [arcsec]**					**Depth [mag]**				
(1)	***u'* *(2)***	***g'* *(3)***	***r'* *(4)***	***i'* *(5)***	***z'* *(6)***	***u'* *(7)***	***g'* *(8)***	***r'* *(9)***	***i'* *(10)***	***z'* *(11)***
HCG 86	-	1	0.65	1.49	-	-	26.64	25.60	24.51	-
NGC 3311	-	0.85	0.81	-	-	-	25.60	24.99	-	-
NGC 3379	0.77	0.83	0.86	-	-	24.23	25.40	24.99	-	-
NGC 3640	0.82	0.41	0.40	0.50	-	24.53	25.20	24.84	24.14	-
PGC 007748	-	0.72	0.67	-	-	-	25.79	25.00	-	-
PGC 015524	-	0.47	0.60	-	-	-	25.42	25.32	-	-

PGC 049940	-	0.75	0.51	-	-	-	25.70	25.15	-	-
ES1-1	-	0.74	0.72	0.81	-	-	28.05	27.43	26.50	-
ES1-2	-	0.73	0.55	0.78	-	-	28.35	28.33	26.82	-
ES1-3	-	0.65	0.57	0.83	-	-	28.99	28.78	22.13	-
ES1-4	-	0.75	0.84	0.88	-	-	26.92	27.03	26.74	-
M16-A	-	-	-	0.81	0.81	-	-	-	23.25	22.25
M16-B	-	-	-	0.79	0.79	-	-	-	22.75	21.85
M16-C	-	-	-	0.63	0.62	-	-	-	22.63	21.70
M16-D	-	-	-	0.74	0.74	-	-	-	22.69	21.75
M16-E	-	-	-	0.72	0.76	-	-	-	22.34	21.43
M16-F	-	-	-	0.70	0.71	-	-	-	22.06	21.07
M16-G	-	-	-	0.63	0.61	-	-	-	22.51	21.67
M16-H	-	-	-	0.51	0.49	-	-	-	22.43	21.56
M16-I	-	-	-	0.52	0.51	-	-	-	21.75	21.03
N12-A	-	-	-	0.67	0.69	-	-	-	21.95	21.13
N12-B	-	-	-	0.52	0.49	-	-	-	21.10	20.39
N12-C	-	-	-	0.59	0.63	-	-	-	21.34	20.56
N12-D	-	-	-	0.63	0.63	-	-	-	20.99	19.66
S-M16-J	-	-	-	0.5	0.5	-	-	-	22.46	21.63
S-M16-K	-	-	-	0.42	0.52	-	-	-	21.47	20.77
S-M16-L	-	-	-	0.53	0.56	-	-	-	22.36	21.52
S-M16-M	-	-	-	0.39	0.46	-	-	-	22.12	21.37
S-M16-N	-	-	-	0.39	0.46	-	-	-	22.06	21.26
Carina	-	0.91	0.77	-	-	-	24.61	24.01	-	-
ESO 270-017	-	0.73	0.73	-	-	-	24.86	24.39	-	-
ESO 274-001	-	0.82	0.75	-	-	-	24.14	23.51	-	-
NGC 3109	-	0.81	0.72	-	-	-	24.93	24.23	-	-
NGC 3521	-	0.68	0.70	-	-	-	24.83	24.53	-	-
NGC 4945	-	0.77	0.85	-	-	-	24.85	24.32	-	-
NGC 5068	-	0.84	0.67	-	-	-	24.81	24.33	-	-
NGC 5128	-	0.78	0.72	-	-	-	24.98	24.51	-	-
NGC 5236	-	1.02	1.03	-	-	-	24.91	24.49	-	-
NGC 6744	-	0.89	0.68	-	-	-	24.90	24.52	-	-
NGC 7090	-	0.88	0.71	-	-	-	25.03	24.65	-	-

Sextans B	-	0.76	0.76	-	-	-	24.84	24.35	-	-
WLM	-	0.98	0.89	-	-	-	24.86	24.49	-	-
MACS J1115	-	0.97	0.91	-	-	-	24.68	24.19	-	-
MACS J1206	-	0.53	0.60	-	-	-	24.67	24.20	-	-
MACS J1311	-	0.93	1.04	-	-	-	24.60	24.23	-	-
MACS J1931	-	0.72	0.79	-	-	-	23.86	23.08	-	-
MS 2137	-	1.27	1.41	-	-	-	24.53	24.12	-	-
RX J1347	-	0.85	0.88	-	-	-	24.66	24.26	-	-
RXJ2248	-	-	0.78	0.80	-	-	25.80	25.88	-	-

Table 2. Data quality of data in this collection. In column 1 is given the target name. From columns 2 to 6 are reported the average FWHM seeing, in the u', g', r', i', and z' bands, respectively. From columns 7 to 11 are reported the limiting magnitude for a point-source computed at 5σ of the background level, in the u', g', r', i', and z' bands, respectively.

Data Format

Files Types

The files are in FITS format, with the relevant information in the header. They have been compressed using NASA's HEASARC's fpack routine (https://heasarc.gsfc.nasa.gov/fitsio/fpack/).
Each science frame is accompanied by a weight frame. Files are named based on the field covered and the filter used for observations following the format:

<TargetName>_<FilterName>_sci.fits.fz for science images and
<TargetName>_<FilterName>_wei.fits.fz for weight maps.

Acknowledgements

According to the Data Access Policy for ESO data held in the ESO Science Archive Facility, all users are required to acknowledge the source of the data with appropriate citation in their publications.

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- *Based on data obtained from the ESO Science Archive Facility under request number <request_number>.*

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The published papers based on the data in this collection are:

[1] Spavone, M., Krajnovic, D., Emsellem, E., et al., “Assembly history of massive galaxies. A pilot project with VEGAS deep imaging and M3G integral field spectroscopy” 2021, A&A, 649, A161
[2] Ragusa, R., Spavone, M., Iodice, E., et al., “VEGAS: A VST Early-type GAlaxy Survey. VI. Diffuse light in HCG 86 as seen from the ultra-deep VEGAS images” 2021, A&A, 651, A39
[3] Ragusa, R., Mirabile, M., Spavone, M., et al., “The Intra-Group Baryons in the LEO I Pair From the VST Early-Type GAlaxy Survey” 2022, Frontiers in Astronomy and Space Sciences, 9, 852810
[4] Spavone, M., Iodice, E., Lohmann, F.S., et al., “Galaxy populations in the Hydra I cluster from the VEGAS survey: III. The realm of low surface brightness features and intra-cluster light” 2024, A&A, 689, A306